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Abstract The Lagrangian puff-models are widely used for calculation of the dispersion of atmospheric releases. Basic output from such models are concentrations of material in the air and on the ground. The most simple method for calculation of the gamma dose from the concentration of airborne activity is based on semi-infinite cloud model. This method is however only applicable for points far away from the release point. The exact calculation of the cloud dose using the volume integral requires significant computer time.

The volume integral for the gamma dose could be approximated by using the semi-infinite cloud model combined with correction factors. This type of calculation procedure is very fast, but usually the accuracy is poor due to the fact that the same correction factors are used for all isotopes.

The authors describe a more elaborate correction method. This method uses precalculated values of the gamma-dose rate as a function of the puff dispersion parameter (σ_p) and the distance from the puff centre for four energy groups. The release of energy for each radionuclide in each energy group has been calculated and tabulated. Based on these tables and a suitable interpolation procedure the calculation of gamma doses takes very short time and is almost independent of the number of radionuclides.

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Contents

1 Introduction

The mesoscale dispersion model RIMPUFF (Thykier-Nielsen and Mikkelsen, 1987) is a fast and operational computer code suitable for real-time simulation of dispersion environmentally hazardous materials and gases released to the atmosphere. Suitable as a real-time model for emergency preparedness, it has recently been selected for inclusion in the CEC RODOS, real time decision support system under development at KfK.

RIMPUFF includes models for calculating external gamma-doses from air-borne as well as deposited radioactivity. In order to improve these, very simple, models KFKI AERI and Risø has started a joint project supported by the CEC. The first results are reported below.

2 Risø Puff Diffusion Model

The mesoscale dispersion model RIMPUFF applies to non-homogeneous terrain and moderate topography on a horizontal scale of 0 to 50 km, and responds to changing (instationary) meteorological conditions. The Lagrangian puff-model simulates time changing continuous releases by sequentially releasing a series of Gaussian shaped puffs at fixed release rate on a specified grid. The amount of radioactive material allocated to individual puffs equals the release rate times the elapsed time between puff releases.

RIMPUFF is equipped with computer time effective features for terrain and stability-dependent dispersion parametrization, plume rise formulas, inversion and ground-level reflection capabilities and wet/dry (source) depletion. In addition, the code optionally provides local relative diffusion parametrization and scheme for horizontal/vertical shear diffusion.

When applied to orographically influenced dispersion scenarios, RIMPUFF is advantageously interfaced with a high resolution mean flow-model such as LINCOM. This enables the model to treat plume bifurcation in complex terrain by use of the puff pentafurcation scheme.

3 Present Gamma-Dose Model

The present gamma-dose model used in RIMPUFF is based on the semi-infinite cloud model with correction factors given in (Slade, 1968). The model starts by calculating the concentration X_{puff} (0,0,0) in the center of each puff and the distance, R, from the puff-center to each grid point.

The gamma-dose rate in grid point is then calculated using formula:

$$d_\gamma = \Sigma_E f(E_\gamma) E_\gamma \; 0.2292 \; GKOR(\sigma, R/\sigma) GKOR1(\sigma, E_\gamma) \; X_{puff}(0,0,0)$$

where

$f(E_\gamma)$	frequency of photons in energy group
E_γ	mean energy of gamma radiation in energy group [MeV]
$GKOR(\sigma,R/\sigma)$	correction factor for variation of doses with distance and dispersion parameter from fig. 7.14 in (Slade, 1968).
$GKOR1\ (\sigma,E_\gamma)$	correction factor for variation of doses with photon energy from fig. 7.16 in (Slade, 1968). This factor is > 1 for $E_\gamma < 0.7$ MeV and < 1 for $E_\gamma > 0.7$ MeV.
σ	dispersion parameter, where $\sigma=\sqrt{\sigma_{xy}\sigma_z}$
$X_{\gamma,g}(0,0,0)$	activity concentration in puff center [Ci/m^3].

4 Calculation Method for Gamma Dose Rates from Spherical Puffs

The gamma-dose rate calculation method described above is based on the cylindrical plume model. For a puff model the use of a semi-infinite cloud model may lead to large errors. Therefore we have implemented a method for calculation of gamma-dose rates based on a spherical puff model. This method is described in detail below.

The gamma dose rate for a spherical puff using volume integral at point R is equal to

$$d(Q,E_\gamma,\sigma_p,R)=4K\sigma_{a}E_\gamma\int_{x=0}^{\infty}\int_{y=0}^{\infty}\int_{z=-\infty}^{\infty}\frac{B(\mu r)}{4\pi r^2}e^{-\mu r}X(x,y,x)\,dxdydz \quad Gy/sec$$

where

Q	activity in one puff [Bq] with 1 photon/disintegration
E_γ	energy of gamma radiation [MeV]
σ_p	puff parameter [m], $\sigma_p = (\sigma_{xy}{}^2\ \sigma_z)^{1/3}$
R	distance of the puff center (x=y=z=0) from the receptor point [m]
K	constant, $1.6\cdot10^{-13}$ [Gy/sec/MeV/kg]
σ_a	energy absorption coefficient for air [m^2/kg]
B	build up factor
μ	linear attenuation factor for air [m^{-1}]
r	distance of the volume dxdydz from the receptor point located at the distance R from the puff center $r^2 = x^2 + y^2 + (z+R)^2$
$X(x,y,z)$	the concentration in point x,y,z [Bq/m^3]

$$X(x,y,z)=\frac{Q}{(2\pi)^{3/2}\sigma_p^3}\exp(-\frac{l^2}{2\sigma_p^2})$$

l distance of the point x,y,z from the puff center [m],
$l^2 = x^2 + y^2 + z^2$

Calculations were made using the following set of numerical data:

Q $1/E_\gamma$ (in this case 5; 2; 1 and 0.5 Bq respectively)
E_γ 0.2; 0.5; 1 and 2 MeV
B Capo polynomials and Risø data for energy 0.2 MeV from (Jensen and Thykier-Nielsen, 1980)
σ_p range 2 - 5000 m (11 values)
R/σ_p range 0 - 1000 (17 values)
σ_m data of (Storm 1967) reproduced in (Lauridsen, 1982)
μ for air data interpolated from (Thykier, 1978). The numerical values are:
0.2 MeV - $1.60 \cdot 10^{-2}$
0.5 MeV - $1.14 \cdot 10^{-2}$
1.0 MeV - $8.30 \cdot 10^{-3}$
2.0 MeV - $5.70 \cdot 10^{-3}$ m^{-1}

The other values were chosen so that the total error of the calculations is minimized. Special attention was paid to the values of the volume integral close to the receptor point *r*. For *B* outside the of range of approximation, the last acceptable value has been used in each case. The infinite cloud model was used for large σ_p (usually above 500m) where it gives more reliable data than the numerical integration.

It is assumed that the ground surface is totally reflecting. This is taken in to account by modelling the puff as a perfect sphere, which is "folded" at the ground surface, as shown in fig. 1. The implication of this model is that due to symmetry both the semi-infinite (with reflection) and the infinite (without ground reflection) puff gamma dose model give the same gamma-dose rate at ground level.

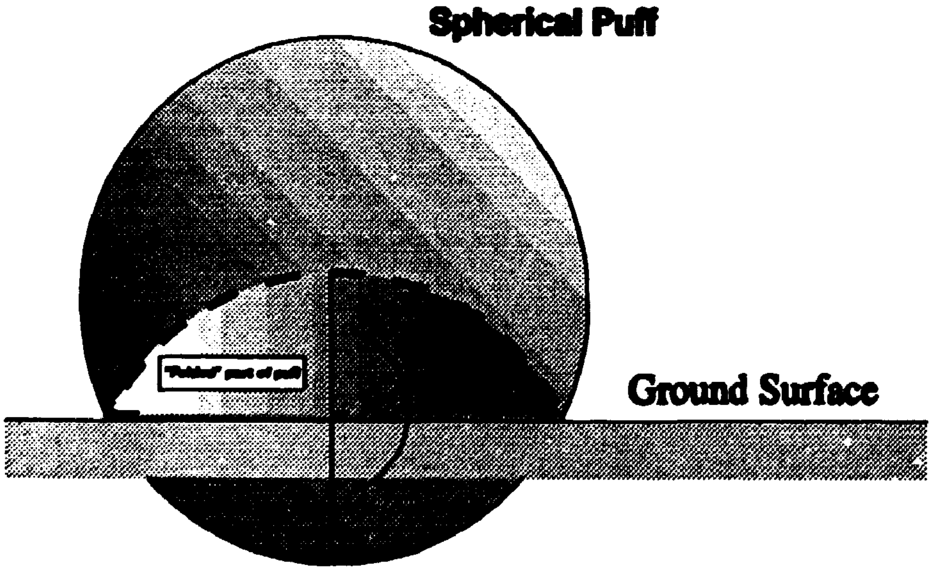

Figure 1. *Reflection of Puff at Ground Level.*

The results of calculations are given in tables 1-4 for energies 0.2, 0.5 1 and 2 MeV. Table 5 contains data for the semi-infinite (infinite) cloud model. On fig. 2. the dose constants are given as a function of distance from the puff center for different σ_p values at gamma-energy 2 MeV. For comparison the infinite cloud model curve is also shown for σ_p=10 m. The infinite cloud model overestimates the gamma dose for small values of R and it underestimates the doses for large values of R.

Fig. 3 illustrates the spatial distribution of dose rates for two different energies. Close to the puff center the dose rate decreases with increasing energy. At large distances from the puff center the situation is the opposite. Fig. 4. shows the dose rate as a function of σ_p for different R values. It should be noticed that the maximum dose rates are obtained for R equal to twice the value of σ_p. The dotted line indicates the dose rates calculated by the semi-infinite cloud model.

On fig. 5 the ratio of infinite cloud model values to numerical integration values are shown as a function of σ_p for 4 values of R/σ_p at 0.2 and 2 MeV. Ratio > 1 for these two models can be found above σ_p between 200 and 1000 m. A part of the increase of the ratio at large σ_p is caused by the extrapolation of B out of its validity range. Consequently the semi-infinite model dose constants are used in all tables and figures for σ_p exceeding the aforementioned values.

Based on the data given in tables 1-5 the gamma-dose rate can be calculated. In these tables the logarithms of dose rates in Gy/s are given for 1 MeV release in the puff as a function of σ_p and the ratio R/σ_p. When the activity of different radionuclides in a puff is known ,then the simplest method is to divide the gamma energies of different gamma-radiation lines into several groups.
An example of the division in to energy groups is:

group 1		E ≤ 0.35 MeV
group 2	0.35 MeV	< E ≤ 0.75 MeV
group 3	0.75 MeV	< E ≤ 1.5 MeV
group 4	1.5 MeV	< E

For each radionuclide the library must contain the energy release rate (MeV/s) for unit activity in each energy group. Using the library, the puff inventory and the dispersion parameter the dose rate for each energy group can be calculated for a given distance R from the puff center. For values not given in tables 1 - 4 a two dimensional linear or logarithmic interpolation must be carried out. The full cloud gamma dose-rate is the sum of dose rates from the four energy groups.

The energy emission data for 22 nuclides (mainly fission products) typically released into the atmosphere are given in table 6.

5 Comparison of Spherical and Cylindrical Models

Based on data given in tables 1 - 4 a comparison with Slade's figures has been carried out. In fig. 6 the Slade's figure 7.14 is reproduced (continuous line). In the same figure the results for spherical model are also shown (dotted line). For small relative y (given in σ units) and large σ values the difference between the results of two models is insignificant, but for other cases it can reach a factor of 5 and in some combinations even more. Smaller differences can be found in fig. 7 (equal to fig. 7.16 in Slade) for energy dependence.

The method given in paragraph 3 may also be used for creating a database for the spherical model. In table 7 the numerical values of the correction factor are given for 6 values of σ_y and y (in the present paper it is equal to *R*) and for 4 energies. For any combination of parameters a suitable interpolation method could be set-up to yield correction factors for the modified semi-infinite cloud calculation procedure presently used in the RIMPUFF model.

6 Conclusions

The method described will significantly improve the procedure for calculation of the gamma-radiation doses from puffs. The main limitation of the method described is that it is, strictly speaking, only applicable to spherical puffs. For puffs where there are significant differences between the values of σ_y and σ_z, this could lead to large errors. For some combinations of σ-values and receptor point locations, the method described will lead to either under- or over-estimation of the gamma-doses.

The gamma dose model for asymmetrical puffs will be developed within the framework of a the CEC RODOS contract in co-operation between Risø and AERI.

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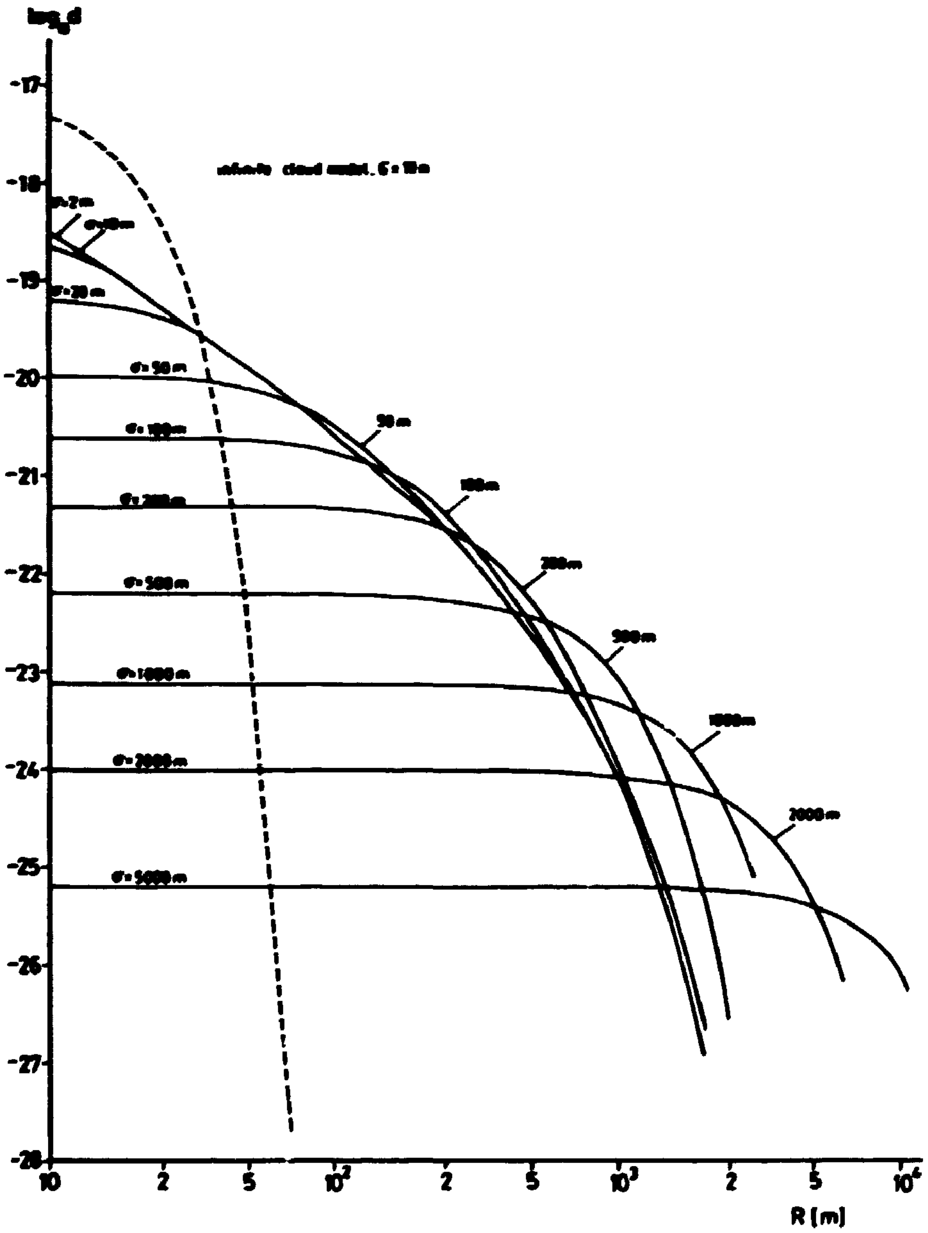

Figure 2. Normalized dose rates in Gy/s for E_γ = 2 MeV as a function of distance at several σ_y-values.

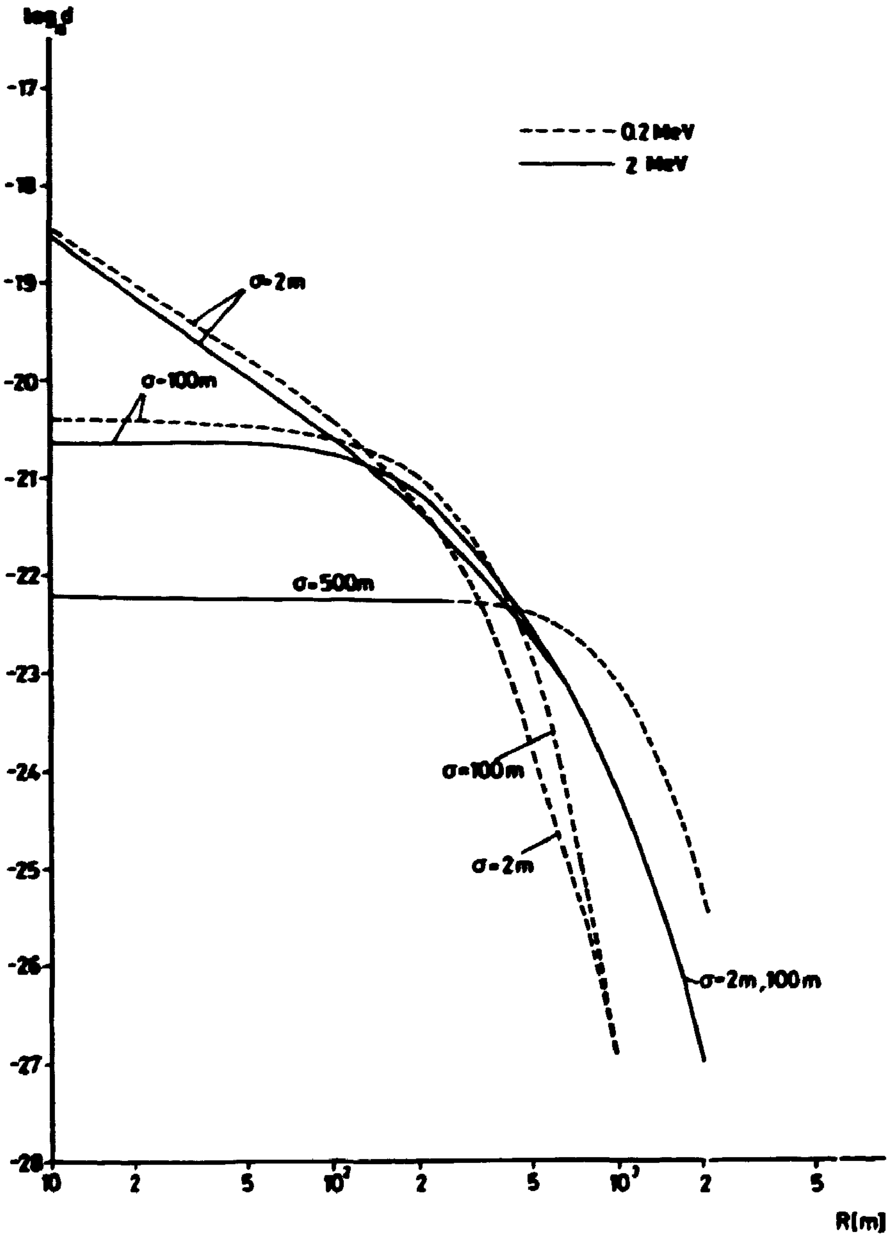

Figure 3. *Normalized dose rates in Gy/s for E_γ = 0.2 and 2 MeV as a function of distance at several σ_p-values. (At σ_p = 500 m the curves coincide).*

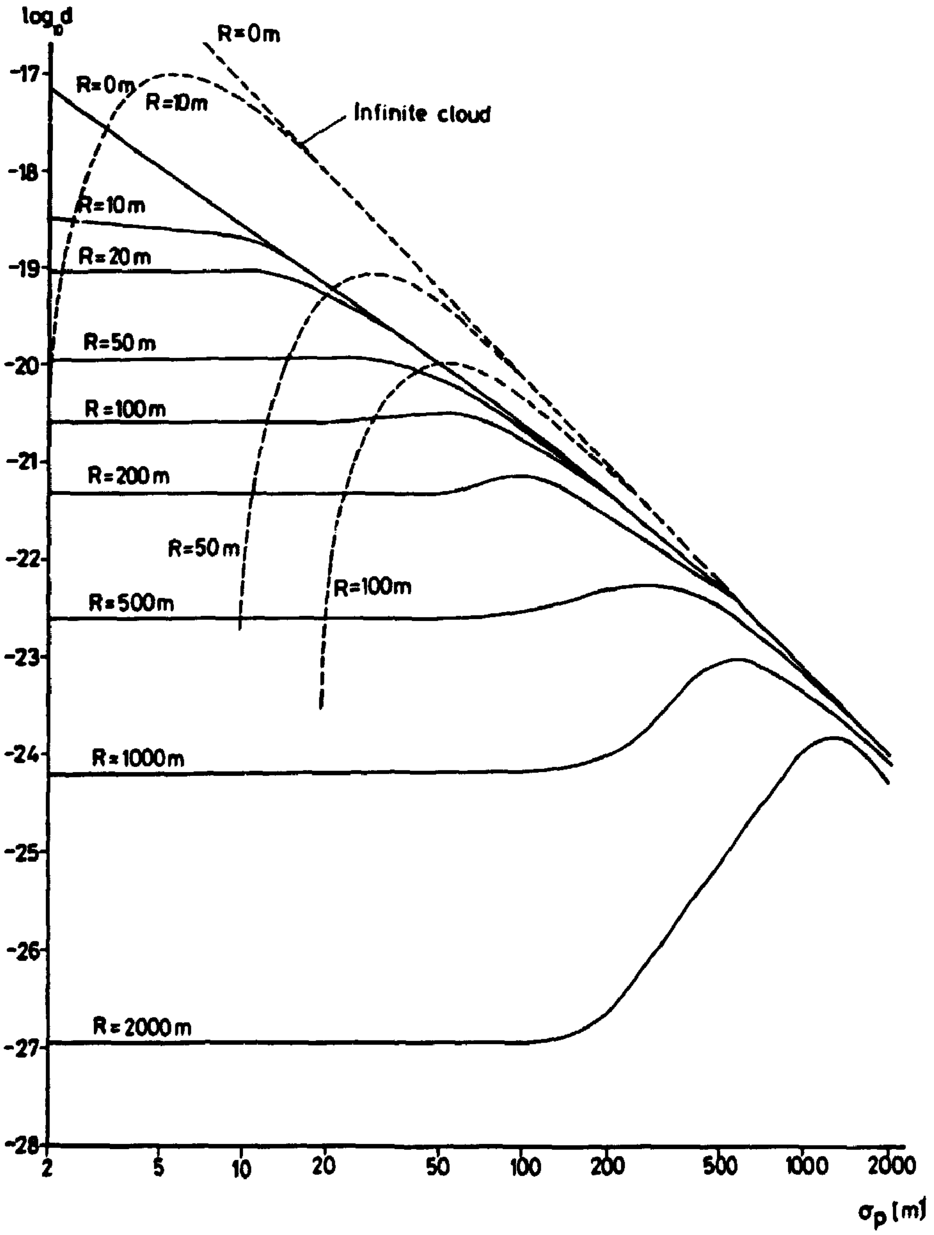

Figure 4. Normalized dose rates in Gy/s for E_γ = 2 MeV as a function of σ_p-values at several distances R. The semi-infinite model results are also shown for four distances R.

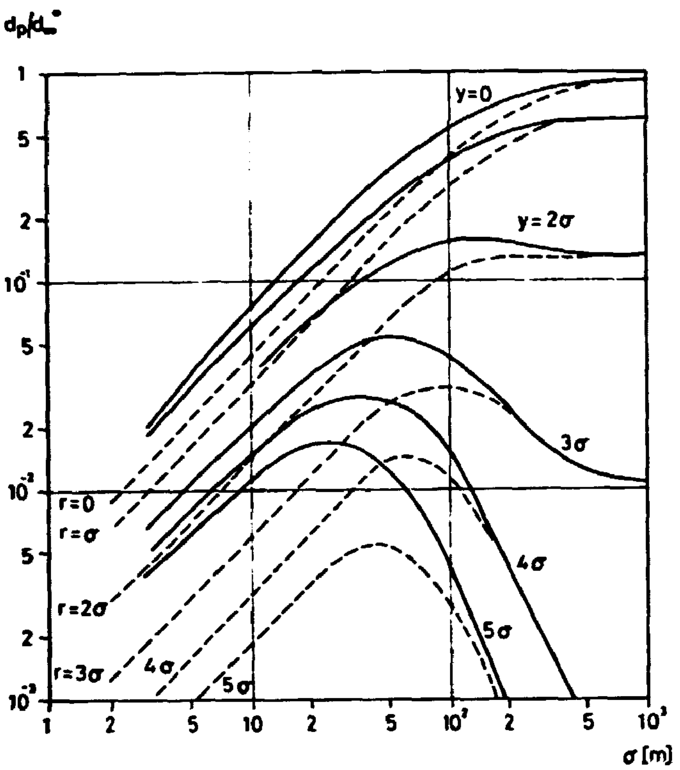

Figure 5. *The ratio of infinite cloud model values to numerical integration values as a function of σ_p for 4 values of R/σ_p at 0.2 and 2 MeV.*

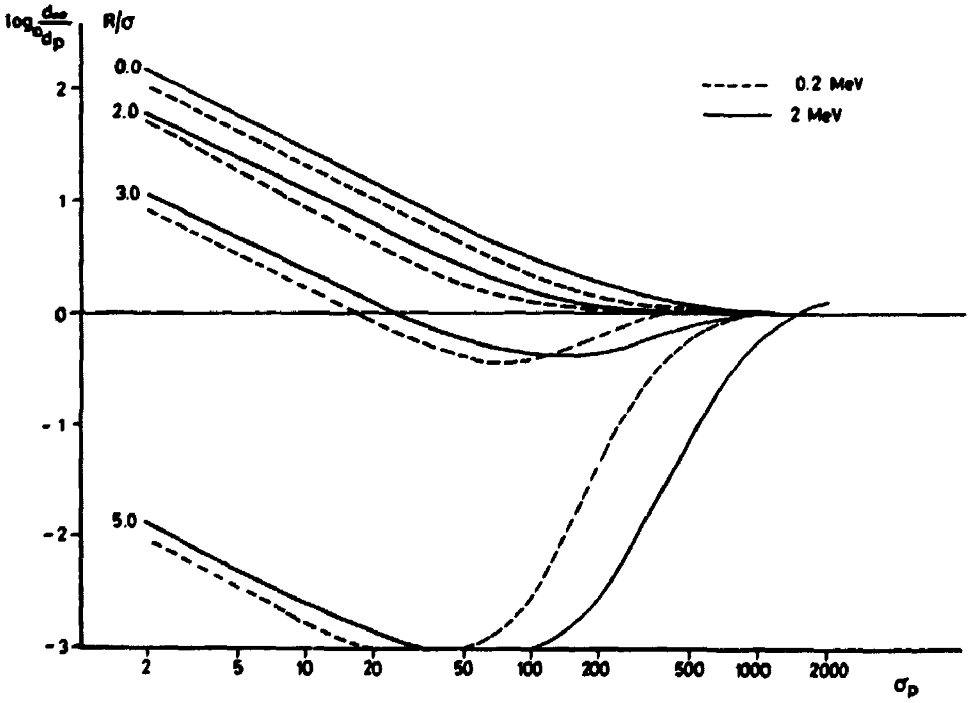

Figure 6. *Ratio of gamma dose rates to puff center dose rate for several distances as function of σ-values. Continuous line - after (Slade, 1968), dotted line - recent calculations for spherical puffs.*

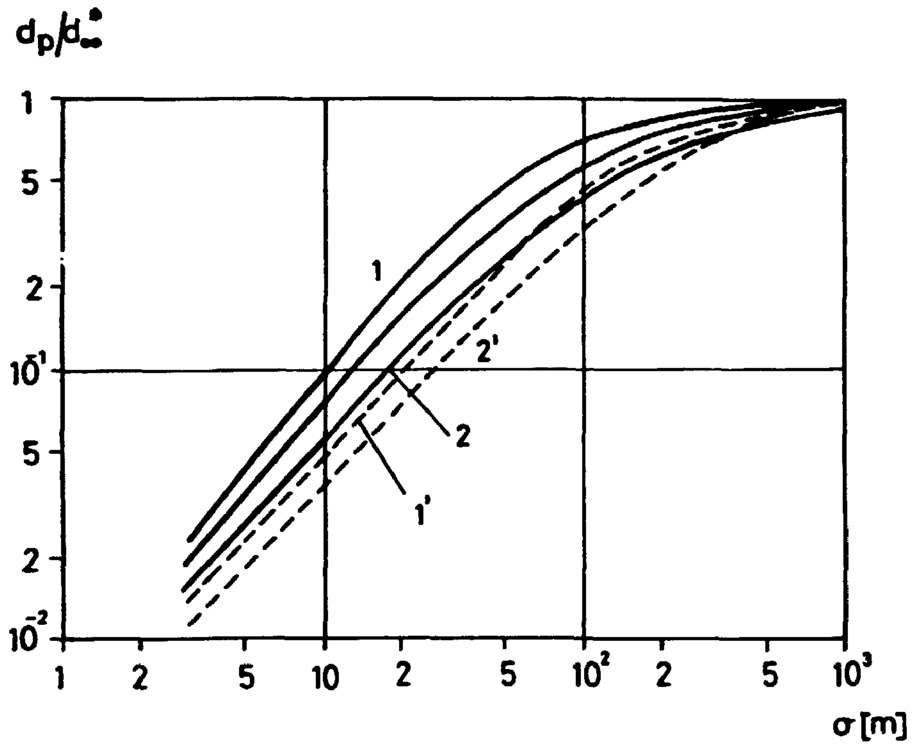

Figure 7. *Ratio of gamma dose rates to puff center dose rate for several energies as function of σ-values. Continuous line - after (Slade, 1968), dotted line - recent calculations for spherical puffs. (Values of E_γ: 1 - 0.1 MeV, 2 - 0.7 MeV, 3 - 2 MeV, 1' - 0.2 MeV, 2' - 2 MeV*

Table 1. Logarithms of normalized dose rates in Gy/s for E_γ = 0.2 MeV

R/σ	σ_z[m]										
	2	5	10	20	50	100	200	500	1000	2000	5000
0	-17.06	-17.85	-18.44	-19.02	-19.80	-20.43	-21.16	-22.20	-23.10	-24.00	-25.20
0.2	-17.07	-17.86	-18.44	-19.03	-19.80	-20.44	-21.16	-22.21	-23.11	-24.01	-25.21
0.4	-17.09	-17.87	-18.46	-19.04	-19.82	-20.46	-21.19	-22.23	-23.14	-24.04	-25.23
0.6	-17.11	-17.90	-18.49	-19.07	-19.85	-20.49	-21.22	-22.28	-23.18	-24.08	-25.28
0.8	-17.15	-17.94	-18.53	-19.11	-19.89	-20.53	-21.27	-22.34	-23.24	-24.14	-25.34
1	-17.20	-17.99	-18.57	-19.15	-19.94	-20.59	-21.34	-22.41	-23.32	-24.22	-25.41
1.3	-17.29	-18.07	-18.66	-19.24	-20.03	-20.69	-21.46	-22.56	-23.47	-24.37	-25.56
1.6	-17.39	-18.17	-18.76	-19.34	-20.13	-20.82	-21.62	-22.75	-23.66	-24.56	-25.75
2	-17.55	-18.33	-18.91	-19.49	-20.30	-21.03	-21.87	-23.07	-23.97	-24.87	-26.07
3	-17.92	-18.69	-19.27	-19.85	-20.75	-21.64	-22.73	-24.15	-25.05	-25.96	-27.15
5	-18.40	-19.16	-19.74	-20.38	-21.54	-22.94	-25.08	-27.42			
7	-18.69	-19.45	-20.04	-20.76	-22.21	-24.40	-28.02				
10	-18.99	-19.75	-20.39	-21.25	-23.23	-26.81	-32.60				
30	-19.91	-20.86	-21.95	-24.20	-31.13						
100	-21.26	-23.37	-27.45	-34.98							
300	-24.23	-31.28									
1000	-35.00										

Table 2. Logarithms of normalized dose rates in Gy/s for E_γ = 0.5 MeV

R/σ	σ_p[m]										
	2	5	10	20	50	100	200	500	1000	2000	5000
0	-17.04	-17.84	-18.44	-19.05	-19.85	-20.49	-21.19	-22.20	-23.10	-24.00	-25.20
0.2	-17.05	-17.84	-18.45	-19.05	-19.86	-20.49	-21.19	-22.21	-23.11	-24.01	-25.21
0.4	-17.06	-17.86	-18.46	-19.07	-19.87	-20.51	-21.21	-22.23	-23.14	-24.04	-25.23
0.6	-17.09	-17.89	-18.49	-19.10	-19.90	-20.54	-21.25	-22.28	-23.18	-24.08	-25.28
0.8	-17.13	-17.93	-18.53	-19.13	-19.94	-20.58	-21.30	-22.34	-23.24	-24.14	-25.34
1	-17.18	-17.97	-18.58	-19.18	-19.99	-20.64	-21.36	-22.41	-23.32	-24.22	-25.41
1.3	-17.27	-18.06	-18.67	-19.27	-20.08	-20.74	-21.48	-22.56	-23.47	-24.37	-25.56
1.6	-17.37	-18.17	-18.77	-19.38	-20.19	-20.86	-21.56	-22.75	-23.66	-24.56	-25.75
2	-17.53	-18.33	-18.93	-19.53	-20.36	-21.05	-21.87	-23.07	-23.97	-24.87	-26.07
3	-17.91	-18.71	-19.31	-19.92	-20.80	-21.61	-22.63	-24.15	-25.05	-25.96	-27.15
5	-18.41	-19.21	-19.82	-20.45	-21.48	-22.67	-27.48	-27.18			
7	-18.71	-19.51	-20.13	-20.80	-22.04	-23.67	-26.39				
10	-19.03	-19.83	-20.47	-21.22	-22.82	-25.14	-29.29				
30	-20.00	-20.89	-21.82	-23.38	-27.77						
100	-21.23	-22.88	-25.37	-30.39							
300	-23.39	-27.83									
1000	-30.41										

Table 3. Logarithms of normalized dose rates in Gy/s for E_γ = 1.0 MeV

R/σ	σ_p[m]										
	2	5	10	20	50	100	200	500	1000	2000	5000
0	-17.07	-17.87	-18.47	-19.07	-19.89	-20.53	-21.23	-22.20	-23.10	-24.00	-25.20
0.2	-17.08	-17.87	-18.47	-19.08	-19.89	-20.53	-21.24	-22.21	-23.11	-24.01	-25.21
0.4	-17.09	-17.89	-18.49	-19.10	-19.91	-20.55	-21.26	-22.23	-23.14	-24.04	-25.23
0.6	-17.12	-17.92	-18.52	-19.12	-19.94	-20.59	-21.29	-22.28	-23.18	-24.08	-25.28
0.8	-17.16	-17.95	-18.56	-19.16	-19.98	-20.63	-21.34	-22.34	-23.24	-24.14	-25.34
1	-17.21	-18.00	-18.61	-19.21	-20.03	-20.68	-21.40	-22.41	-23.32	-24.22	-25.41
1.3	-17.30	-18.09	-18.70	-19.30	-20.12	-20.79	-21.52	-22.56	-23.47	-24.37	-25.56
1.6	-17.40	-18.20	-18.80	-19.41	-20.24	-20.91	-21.66	-22.75	-23.66	-24.56	-25.75
2	-17.56	-18.35	-18.96	-19.57	-20.40	-21.10	-21.90	-23.07	-23.97	-24.87	-26.07
3	-17.94	-18.74	-19.34	-19.96	-20.85	-21.64	-22.62	-24.15	-25.05	-25.96	-27.15
5	-18.44	-19.24	-19.85	-20.50	-21.52	-22.61	-24.21	-26.97			
7	-18.74	-19.55	-20.17	-20.86	-22.04	-23.44	-25.72				
10	-19.06	-19.87	-20.52	-21.28	-22.72	-24.61	-27.94				
30	-20.04	-20.95	-21.84	-23.17	-26.60						
100	-21.28	-22.75	-22.75	-24.75	-28.48						
300	-23.17	-26.63									
1000	-28.49										

Table 4. Logarithms of normalized dose rates in Gy/s for E_γ = 2.0 MeV

R/σ	σ_p[m]										
	2	5	10	20	50	100	200	500	1000	2000	5000
0	-17.15	-17.94	-18.55	-19.15	-19.97	-20.60	-21.29	-22.20	-23.10	-24.00	-25.20
0.2	-17.15	-17.95	-18.55	-19.16	-19.97	-20.61	-21.29	-22.21	-23.11	-24.01	-25.21
0.4	-17.17	-17.97	-18.57	-19.18	-19.99	-20.63	-21.32	-22.23	-23.14	-24.04	-25.23
0.6	-17.20	-18.00	-18.60	-19.20	-20.02	-20.66	-21.35	-22.28	-23.18	-24.08	-25.28
0.8	-17.24	-18.03	-18.64	-19.24	-20.06	-20.70	-21.40	-22.34	-23.24	-24.14	-25.34
1	-17.28	-18.08	-18.69	-19.29	-20.11	-20.75	-21.45	-22.41	-23.32	-24.22	-25.41
1.3	-17.37	-18.17	-18.77	-19.38	-20.20	-20.85	-21.57	-22.56	-23.47	-24.37	-25.56
1.6	-17.48	-18.27	-18.88	-19.49	-20.31	-20.97	-21.70	-22.75	-23.66	-24.56	-25.75
2	-17.63	-18.43	-19.04	-19.65	-20.48	-21.16	-21.92	-23.07	-23.97	-24.87	-26.07
3	-18.02	-18.82	-19.43	-20.05	-20.91	-21.67	-22.58	-24.00	-25.05	-25.96	-27.15
5	-18.51	-19.32	-19.94	-20.58	-21.55	-22.51	-23.87	-26.50			
7	-18.82	-19.63	-20.26	-20.93	-22.01	-23.18	-25.02				
10	-19.14	-19.95	-20.60	-21.32	-22.58	-24.09	-26.64				
30	-20.12	-21.01	-21.82	-22.94	-25.55						
100	-21.33	-22.60	-24.17	-26.92							
300	-22.94	-25.57									
1000	-26.92										

Table 5. Logarithms of normalized dose rates in Gy/s for semi-infinite cloud model

R/σ	σ_z[m]										
	2	5	10	20	50	100	200	500	1000	2000	5000
0	-15.00	-16.20	-17.10	-18.00	-19.20	-20.10	-21.00	-22.20	-23.10	-24.00	-25.20
0.2	-15.01	-16.21	-17.11	-18.01	-19.21	-20.11	-21.01	-22.21	-23.11	-24.01	-25.21
0.4	-15.04	-16.23	-17.14	-18.04	-19.23	-20.14	-21.04	-22.23	-23.14	-24.04	-25.23
0.6	-15.08	-16.28	-17.18	-18.08	-19.28	-20.18	-21.08	-22.28	-23.18	-24.08	-25.28
0.8	-15.14	-16.34	-17.24	-18.14	-19.34	-20.24	-21.14	-22.34	-23.24	-24.14	-25.34
1	-15.22	-16.41	-17.32	-18.22	-19.41	-20.32	-21.22	-22.41	-23.32	-24.22	-25.41
1.3	-15.37	-16.56	-17.47	-18.37	-19.56	-20.47	-21.37	-22.56	-23.47	-24.37	-25.56
1.6	-15.56	-16.75	-17.66	-18.56	-19.75	-20.66	-21.56	-22.75	-23.66	-24.56	-25.75
2	-15.87	-17.07	-17.97	-18.87	-20.07	-20.97	-21.87	-23.07	-23.97	-24.87	-26.07
3	-16.96	-18.15	-19.05	-19.96	-21.15	-22.05	-22.96	-24.15	-25.05	-25.96	-27.15
5	-20.43	-21.63	-22.53	-23.43	-24.63	-25.53	-26.43	-27.63	-28.53	-29.43	-30.63
7	-25.64	-26.84	-27.74	-28.64	-29.84	-30.74	-31.64	-32.84	-33.74	-34.64	-35.84
10											
30											
100											
300											
1000											

Table 6. The energy emission data for 22 nuclides typically released into atmosphere

Nuclide	Energy in MeV/decay for group				
	1	2	3	4	5
^{41}Ar	0	0	1.283+0	0	1.283
^{85m}Kr	0	0	0	0	1.561-1
^{87}Kr	0	2.140-1	9.364-2	4.632-1	7.709-1
^{88}Kr	5.704-2	1.572-2	2.166-1	1.619+0	1.908
^{89}Rb	0	0	1.145+0	7.430-1	1.888
^{95}Nb	0	0	7.658-1	0	7.658-1
^{110m}Ag	0	9.302-1	1.593+0	2.157-1	2.739
^{131}I	2.060-2	3.585-1	0	0	3.791-1
^{131}Xe	2.00-2	0	0	0	2.00-2
^{132}I	0	1.013+0	1.152+0	5.639-2	2.222
^{132}Te	2.313-1	0	0	0	2.313-1
^{133}I	0	4.848-1	1.096-1	0	5.944-1
^{133}Xe	4.600-2	0	0	0	4.6-2
^{133m}Xe	4.070-2	0	0	0	4.07-2
^{134}Cs	0	7.322-1	8.226-1	0	1.555
^{134}I	1.466-2	3.320-1	1.896+0	0	2.243
^{135}I	0	6.645-2	9.910-1	4.743-1	1.532
^{135}Xe	2.256-1	1.990-2	0	0	2.455-1
^{135m}Xe	0	4.276-1	0	0	4.276-1
^{137}Cs	0	5.627-1	0	0	5.627-1
^{137}Xe	0	1.367-1	7.227-3	6.955-3	1.508-1
^{138}Xe	1.002-1	1.286-1	5.060-2	7.991-1	1.079

group 1 $E \le 0.35$ MeV

group 2 0.35 MeV $< E \le 0.75$ MeV

group 3 0.75 MeV $< E \le 1.5$ MeV

group 4 1.5 MeV $< E$

group 5 total energy

Table 7. Modified correction factors for [Slade, 1968]

R = 0

σ [m]	E_γ [MeV]			
	0.2	**0.5**	**1.0**	**2.0**
2	**0.0087**	**0.0091**	**0.0085**	**0.0071**
5	**0.0224**	**0.0229**	**0.0214**	**0.0182**
10	**0.046**	**0.046**	**0.043**	**0.0355**
20	**0.095**	**0.089**	**0.085**	**0.071**
50	**0.251**	**0.224**	**0.204**	**0.170**
100	**0.47**	**0.41**	**0.37**	**0.32**
200	**0.69**	**0.65**	**0.59**	**0.51**
500	**1.00**	**1.00**	**1.00**	**1.00**
1000	**1.00**	**1.00**	**1.00**	**1.00**

R = σ

σ [m]	E_γ [MeV]			
	0.2	**0.5**	**1.0**	**2.0**
2	**0.0105**	**0.0110**	**0.0102**	**0.0087**
5	**0.0263**	**0.0275**	**0.0257**	**0.0213**
10	**0.056**	**0.055**	**0.051**	**0.043**
20	**0.118**	**0.110**	**0.102**	**0.085**
50	**0.295**	**0.263**	**0.240**	**0.200**
100	**0.54**	**0.48**	**0.44**	**0.37**
200	**0.76**	**0.72**	**0.66**	**0.59**
500	**0.93**	**0.92**	**0.87**	**0.85**
1000	**1.00**	**1.00**	**1.00**	**1.00**

Table 7. (continuation)

R = 2σ

σ [m]	E_γ [MeV]			
	0.2	0.5	1.0	2.0
2	0.0209	0.0219	0.0204	0.0174
5	0.055	0.055	0.052	0.044
10	0.115	0.110	0.102	0.085
20	0.240	0.219	0.200	0.166
50	0.59	0.51	0.47	0.39
100	0.87	0.83	0.74	0.65
200	1.00	1.00	0.93	0.89
500			1.00	1.00
1000				

R = 3σ

σ [m]	E_γ [MeV]			
	0.2	0.5	1.0	2.0
2	0.110	0.112	0.105	0.087
5	0.288	0.275	0.258	0.213
10	0.60	0.55	0.51	0.42
20	1.29	1.10	1.00	0.81
50	2.51	2.24	2.00	1.74
100	2.57	2.75	2.57	2.40
200	1.70	2.14	2.19	2.40
500	1.00	1.17	1.20	1.41
1000	-	1.00	1.00	1.00

Table 7. (continuation)

R = 4σ

σ [m]	E_γ [MeV]			
	0.2	0.5	1.0	2.0
2	1.8	1.8	1.7	1.4
5	5.2	4.7	4.4	3.7
10	10.5	9.3	8.7	7.1
20	21	18	16	13.3
50	33	33	31	27
100	21	30	31	33
200	8.5	10	14	21
500	1.3	1.8	2.3	3.4
1000	1.0	1.0	1.1	1.2

R = 5σ

σ [m]	E_γ [MeV]			
	0.2	0.5	1.0	2.0
2	107	104	98	83
5	295	260	245	205
10	620	510	480	390
20	1120	950	850	710
50	1230	1410	1290	1200
100	390	724	830	1050
200	22	89	165	360
500	1.6	2.8	4.5	13.5
1000	1.0	1.0	1.2	1.5

Title and authors(s)

Calculation Method for Gamma-Dose Rates from Spherical Puffs

S. Thykier-Nielsen, S. Deme and E. Láng

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Abstract (Max. 2000 characters)

The Lagrangian puff-models are widely used for calculation of the dispersion of atmospheric releases. Basic output from such models are concentrations of material in the air and on the ground. The most simple method for calculation of the gamma dose from the concentration of airborne activity is based on semi-infinite cloud model. This method is however only applicable for points far away from the release point. The exact calculation of the cloud dose using the volume integral requires significant computer time.

The volume integral for the gamma dose could be approximated by using the semi-infinite cloud model combined with correction factors. This type of calculation procedure is very fast, but usually the accuracy is poor due to the fact that the same correction factors are used for all isotopes.

The authors describe a more elaborate correction method. This method uses precalculated values of the gamma-dose rate as a function of the puff dispersion parameter (σ_p) and the distance from the puff centre for four energy groups. The release of energy for each radionuclide in each energy group has been calculated and tabulated. Based on these tables and a suitable interpolation procedure the calculation of gamma doses takes very short time and is almost independent of the number of radionuclides.

Descriptors INIS/EDB

AIR POLLUTION; CALCULATION METHODS; COMPUTERIZED SIMULATION; GAMMA RADIATION; MATHEMATICAL MODELS; METEOROLOGY; NUMERICAL DATA; PLUMES; R CODES; RADIATION DOSES: RADIOISOTOPES

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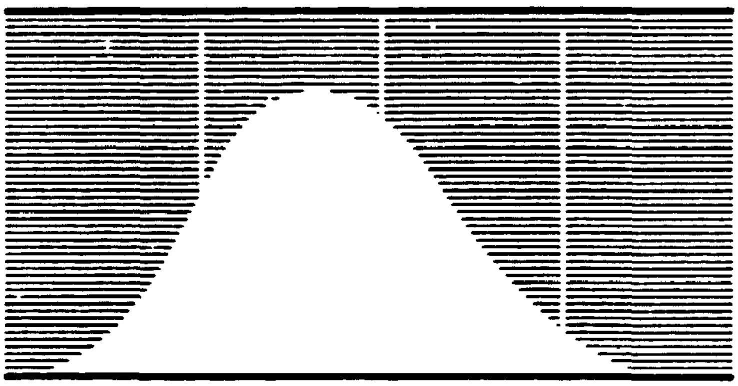

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